

Atmospheric Emissions

of heating options

Depending on the climate, energy consumption for heating can be a major issue in sustainable development. Figure 1 (on the next page) shows greenhouse gas (GHG) emissions for the main heating options. For electric heating, performance depends on the source of the electricity. To illustrate this, five electric heating scenarios are presented: one scenario based on coal-fired generation, one scenario based on the Québec model of 94% hydroelectricity, and three scenarios based on natural-gas-fired generation. The life-cycle data includes emissions from fuel extraction, processing and delivery.

Facts About GHG Emissions

- Conventional electric baseboard heating often has a poor reputation, environmentally speaking. In reality, its performance is poor only when the electricity is mainly generated with coal. When hydroelectricity is used, electric heating clearly has the best environmental performance.
- Among the scenarios where natural gas is the energy source, gas heating produces slightly lower GHG emissions than electric baseboard heating from gas-fired generation. However, for a comparable cost, electric heating (from gas-fired generation) with a heat pump performs better than gas heating.
- Compared with oil, natural gas heating reduces emissions by about 25%.
- GHG emissions caused by wood heating vary widely depending on combustion efficiency. Even with a high- efficiency woodstove, emissions are higher than for hydroelectricity because wood harvesting and transportation operations use equipment fuelled by petroleum products. The efficiency of wood fireplaces is very low and GHG emissions are as high as those from fossil fuels. All this is assuming that the forests are managed in an environmentally sound manner. If every harvested tree is replaced, the amounts of carbon emitted and stored by the biomass should be equal. However, some authors (Houck and Tiegs, 1998) consider this balance doubtful because, in practice, the next harvest may sink less carbon than was already emitted.
- A geothermal heat pump is the most efficient technology, but it costs much more than the other options.

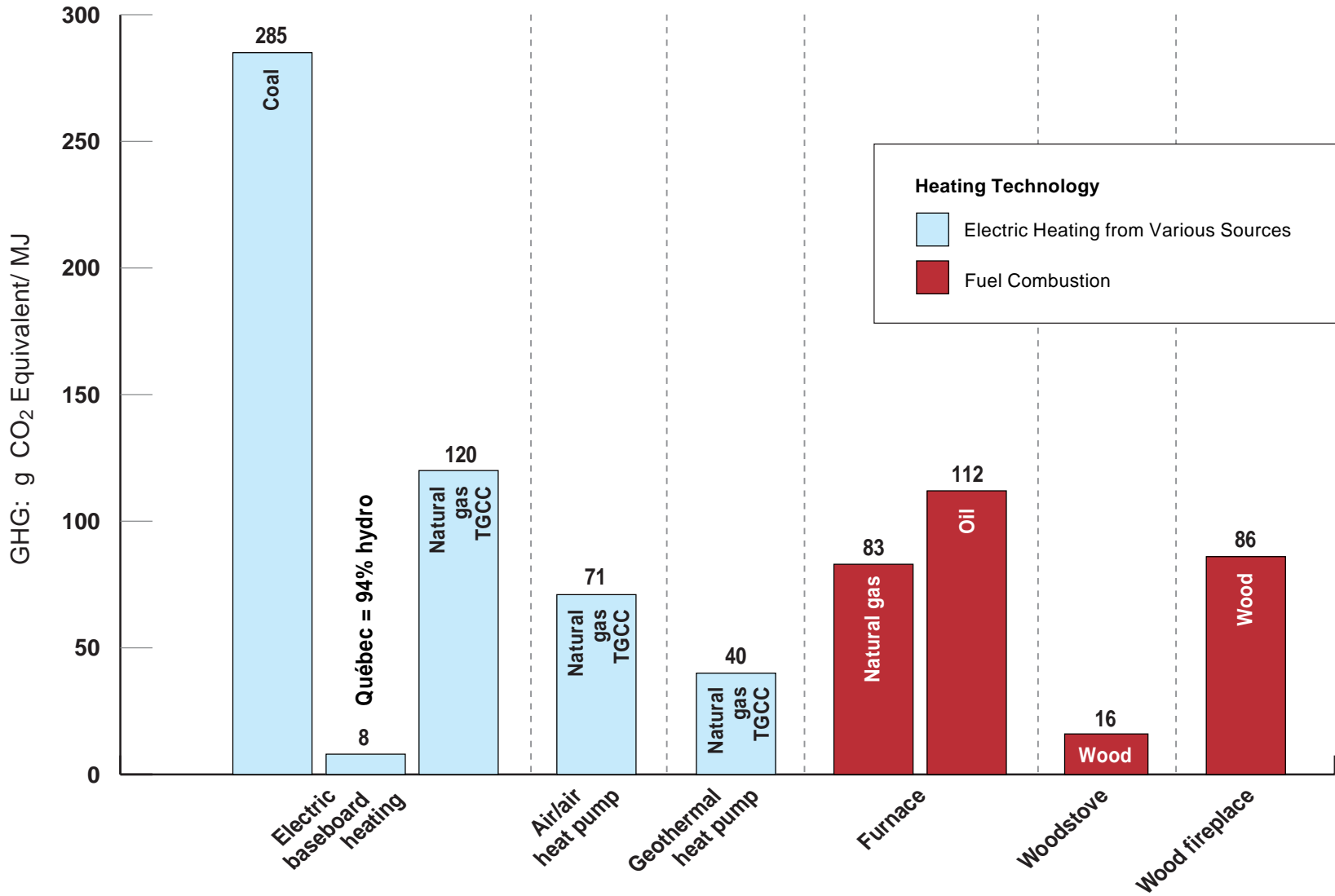
Environmental issues and heating options

Atmospheric emissions are often considered to be the main environmental issue for heating options.

Main Atmospheric Emissions

Environmental Issue	Emissions
Climate change	<ul style="list-style-type: none"> • GHGs: <ul style="list-style-type: none"> - Carbon dioxide CO₂ - Methane CH₄
Acid precipitation	<ul style="list-style-type: none"> • Sulphur dioxide SO₂
Smog, air quality, respiratory illnesses	<ul style="list-style-type: none"> • Nitrogen oxides NO_x • Particulates • Volatile organic compounds (VOC)

Figure 1. GHG Emissions for Residential Heating Options



NB. The efficiency factors used for these ratings are provided in Table 2

Acid Precipitation and Air Quality

Table 1 shows the direct emissions by heating systems of the various pollutants that affect air quality (excluding emissions from other life-cycle components).

Facts

- As far as health risks are concerned, wood heating is in a class of its own, with extremely high emissions of particulates and volatile organic compounds. Only automobile pollution in certain urban areas presents such high risks.
- Heating with oil and natural gas contributes only moderately to urban smog.
- In Québec, light fuel oil contains 0.24% sulphur and is a significant source of acid precipitation. Oil refining is also a source of sulphur emissions.
- Natural gas is a very clean fuel because the sulphur present in deposits is removed during processing before transmission to Québec. Processing plants, however, constitute a significant source of SO₂ in Alberta.

Table 1. Direct Emissions from Heating Options That Affect Air Quality (mg/ MJ)

Technology	Source of Energy	Nitrogen Oxides NO _x	Sulphur Dioxide SO ₂	Particulates	VOC
1. Electric baseboard heating	Electricity	0	0	0	0
2. Air/air heat pump					
3. Geothermal pump					
4. Furnace	Natural gas	48	0 to 1	2 to 4	3
5. Furnace					
6. Woodstove	Wood	68 to 141	14 to 20	700 to 1500	27 to 40
7. Wood fireplace	Wood	≥ 367	≥ 76	≥ 3780	≥ 146

In Québec, is it realistic to replace electric home heating with natural gas heating on a large scale?

This question arises every time projects involving combined-cycle gas turbines (CCGTs) are discussed. At first glance, GHG emissions from natural gas heating would appear to be lower.

However, a more thorough comparison should take into account the additional infrastructure required for gas heating. To replace 5 TWh of electric heating (typical CCGT generation of about 630 MW), 355,000 homes now heated with electricity (consumption of 14,000 kWh/year) would have to be converted to gas. This would involve:

- installing 355,000 furnaces and meters (and chimneys in most cases)
- making 355,000 underground hookups
- building hundreds of kilometres of gas distribution lines

Assuming that 60% of the new customers are in an area already served and 40% would require system extension, the average cost of the extensions and hookups would be \$8,560 per new customer (2001 rate case, R-3444-2000, SCGM-4, document 6). One large CCGT generating station would cost about \$500 million. To replace its contribution with direct gas heating, the cost to taxpayers would be \$3 billion for the distribution systems and homeowner costs would be about \$2 billion for home heating systems.

Heating Appliance Efficiency

All combustion heating systems (natural gas, oil or wood) lose heat for various reasons: changeover in operation, cold start-up, incomplete combustion, heat escaping through the chimney. These losses determine the heating system's efficiency; expressed as a percentage, this indicates how much of the heat generated is actually used to heat the house.

Table 2. Efficiency of Heating Appliances by Technology

Technology	Range of Seasonal Efficiency (%)	Efficiency Used to Calculate Emissions (%)
1. Electric baseboard heating	100	100
2. Air/air heat pump	150 to 200	170
3. Geothermal heat pump	300	300
4. Natural gas furnace	60 to 97	82
5. Oil furnace	60 to 89	78
6. Woodstove	45 to 80	54
7. Wood fireplace	-10 to +10	+10

- "Seasonal efficiency" rates the ability of an appliance to convert energy into heat during an entire season. It takes into account losses related to normal operation, as well as the fact that heating systems often operate for too short a time to achieve a stable efficiency, especially in warmer weather at the beginning and end of the winter
- The efficiency of a conventional fireplace can be negative because more heat than it produces may escape through the chimney
- Heat pump efficiency may exceed 100% because heat pumps transfer heat instead of converting electricity into heat

Health Risks from Wood Heating

Several factors link wood combustion to high health risks.

- Wood heating is often a direct source of pollution inside homes. Occupants can be exposed to pollutants for very long periods.
- According to a study (Anuszewski et al., 1998), wood smoke from home chimneys penetrates neighboring homes; the concentration of particulates was similar outside and inside the homes studied. Wood heating therefore causes exposure to particulates within the "emitting" home and in neighboring homes.
- Wood smoke is more hazardous to health than secondary cigarette smoke. One kg of burning wood can emit 160 µg of dioxins (*Burning Issues*).
- In Québec, woodstoves that use up-to-date technology are very rare. The number of homes heated by wood rose six-fold between 1979 and 1999; consumption of firewood during the same period, as an electrical energy equivalent, rose from 3.0 TWh to 8.7 TWh (assuming woodstove efficiency of 54%).

Wood Fireplaces

According to Natural Resources Canada (1998): *Conventional fireplaces can contaminate indoor air at both the beginning and end of the burn cycle. When a fire is first lit, the chimney is not usually warm enough to properly draw the combustion products to the outdoors. As a result, much of the smoke and gases spill back into the home.*

Table 3. Sources of Data on Atmospheric Emissions from Heating Options

Heating Options	Life Cycle g/MJ	Furnace Efficiency and Direct Emissions mg/MJ				
	GHG Emissions	Efficiency % (1)	NO _x Emissions	SO ₂ Emissions	Particle Emissions	VOC Emissions
Direct combustion heating						
Light fuel oil	89 to 120 112	60 to 89 78 typical (3)	59 (4)	112 (2,4)	2 to 4 (4)	2 (4)
Natural gas	60 to 97 83	67 to 90 82 typical (3)	48 (4)	0 to 1 (4)	2 to 4 (4)	3 (4)
Wood; conventional woodstove	16 to 50 16	≥ 45% 54 typical	141 (4)	20 (4)	1540 (4)	40
Wood; EPA woodstove with catalyser (3)	16 to 34	45 to 80 80 typical (3)	68 (4)	14 (4)	693 (4)	27
Wood; fireplace		-10 to +10				
Electric heating						
2002 profile: 94% hydroelectricity	4 to 8	100	0	0	0	0
Gas with CCGT	120	100	0	0	0	0

1. Natural Resources Canada, EnerGuide 1998. *All About Fireplaces*
EnerGuide 2000. *Heating with Oil*.
EnerGuide 1999. *Heating with Gas*.
2. Environment Canada 2001, p.14, Teneur moyenne en soufre du mazout léger au Québec: 0,240% en poids
3. Energy Efficiency and Renewable Energy Network (EREN). US Department of Energy. January 2001. *EREC Briefs: Comparing Heating Fuels*.
4. United States Environmental Protection Agency (EPA). 2002. *Compilation of Air Pollutant Emission Factors. Stationary Point and Area Sources*. AP-42. Vol. 1, 5th edition.
<http://www.epa.gov/ttn/chief/ap42/>

References

Anuszewski, J., T.V. Larson, and J.Q. Koenig. 1998. "Simultaneous indoor and outdoor particle light-scattering measurements at nine homes using a portable nephelometer". *Journal of Exposure Analysis and Environmental Epidemiology*. Vol. 8, no 4, Oct.-Dec. 1998, p. 483-487.

Burning Issues. (2002). *Carcinogenic Chemicals from Wood and Coal Stoves*.
<http://www.webcom.com/~bi/pah-comp-wood-coal.htm>.

Burning Issues. (2002). *Home Heating Facts and Figures*.
<http://www.webcom.com/~bi/home-heating.htm>.

CUM. (2002). *Fiche 4 Les polluants produits par la combustion du bois*.
<http://www.cum.qc.ca/cum-fr/air-eau/cha4airf.htm>

Energy Efficiency and Renewal Energy Network (EREN). (2001 and 2002).
Air Pollution from Wood-Burning Appliances and Fireplaces.
<http://www.eren.doe.gov/consumerinfo/refbriefs/ja.3.html>.

EPA (2001). *What You Should Know About Combustion Appliances and Indoor Air Pollution*.
<http://www.epa.gov/iap/pubs/combust.html>.

European Parliament. (1998) *L'utilisation du bois à des fins énergétiques : conciliation des rôles écologiques et économiques des forêts*.
<http://www.europarl.eu.int/dg7/forest/fr/s5-17-1.htm>

Filion, P. and Morin, L.-P. 2001. *L'énergie au Québec*. Les publications du Québec. 120 p.

Houck, J. E. and Tiegs P. E. U.S. Environmental Protection Agency, 1998.
Residential Wood Combustion Technology Review. Volume 1, Technical Report. 37 p.

Mann, M. K. and Spath, P. L. 2000. *A Summary of Life Cycle Assessment Studies Conducted on Biomass, Coal, and Natural Gas Systems*. National Renewable Energy Laboratory. 7 p.

Natural Resources Canada. EnerGuide 1998. *All About Wood Fireplaces*.

Wood Burning. (1998). *In a Cloud of Smoke*.
<http://www.district.north-van.bc.ca/admin/depart/enviro/smoke.htm>.

Wood Heating Appliance Options. (1998). *Space Heaters*.
<http://www.wood-heat.com/appltype.htm>.

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